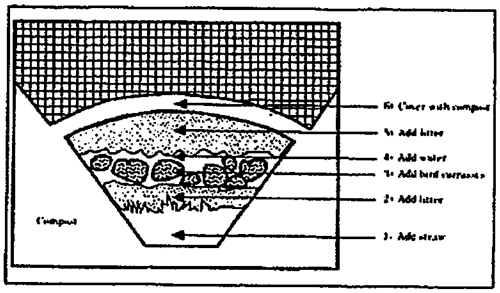

Figure 2.—Loading an in-house composter.

same as for in-house composters, but adjustments can be made to meet individual situations. The time and hand labor required to manage an outside composter must be carefully considered before installation. The cost of an outside single-stage composter varies according to its size, from $500 to $1,500.

Two-stage Composters

A two-stage composter is larger and more expensive than the single-stage composter, but it will accommodate more dead birds. A two-stage composter is also less labor intensive because it relies on mechanized equipment. However, it must be compatible with the management capabilities of the producer. The composting process is done in primary and secondary bins. The following requirements describe the design and lay-out of a two-stage composter.

- The size of the composter is 1 cubic foot of primary bin and 1 cubic foot of secondary bin per pound of daily mortality.
- The height of bins should not exceed 5 feet. Heights greater than 5 feet increase compaction and the potential for overheating.
- The width of the bins is usually selected to accommodate the loading and unloading of equipment. A width of 8 feet is normal, but the bins could be wider.
- Most bins are typically 5 or 6 feet deep, although deeper bins can be used. Longer bins are more difficult to enter and exit and take more time to work.
- Several smaller primary bins work more efficiently than a few large bins. Secondary bins can be larger, but they must have the same capacity as the primary bins (see Fig. 3).

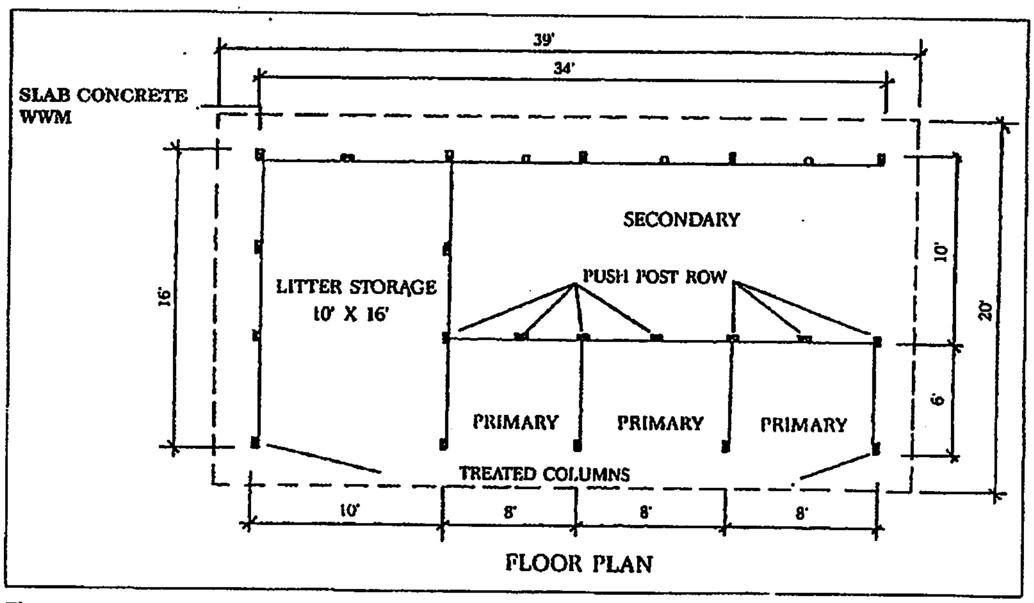

Figure 3.—Typical two-stage composter floor plan (not to scale).

- It is desirable to have extra primary bins in which to store litter and straw. If high mortalities occur, these bins could be used for composting.
- Ceiling height of the composter should be high enough to accommodate a front-end loader extended upward.
- Concrete flooring should be extended beyond the bins sufficiently to allow a tractor or other equipment to work entirely on a concrete surface. Dirt or gravel will rut, dig out, and reduce traction.
- Roof overhang must extend sufficiently to prevent blowing rain from reaching the compost. Side curtains are another option to protect the compost from blowing rain. Maintain dry conditions within the composting structures.
- A composter that has a litter storage facility can greatly enhance the management of dead birds, building cleanout, and litter spreading operations.
- The composting facility should be supplied with fire protection equipment in case the compost self-ignites.
- The composting facility should be equipped with water and electrical services. Water is required for the compost recipe, equipment cleanup, and for the washdown of personnel. Electrical outlets are required for lights and power tools or appliances.

Costs of composters depend on many factors — size, configuration (e.g., work areas, ingredients, and finished compost storage), and utilities. Some composting structures have been built for as little as $500; others, for as much as $50,000. No specific plan or layout for composters works best in all cases. Many different designs will perform adequately, but management capabilities determine the success of the composting process. Standard plans and management information for poultry mortality composters are available through local USDA Soil Conservation Service or Cooperative Extension Service offices.

Financial aid or cost-share funding may be available to help pay for the design and construction of composting facilities. Check with your local conservation district, USDA Soil Conservation Service, or Cooperative Extension Service offices to learn more about these programs.

Composting Recipe

For composting poultry mortalities in a two-stage composter, a prescribed mixture of ingredients is used called a "recipe." The recipe calls for one part dead birds, one part manure and litter, two-to-three parts straw or other carbon source, and zero-to-a-half part water (Table 1). Recipes for a single-stage composter differ slightly.

Table 1.—Typical recipe for composting dead birds with litter, straw and water as ingredients.

INGREDIENTS	PARTS BY WEIGHT
Dead Birds	1.0
Litter or cake	1.5
Straw	0.1
Water*	0.2

***Water as an ingredient may not be necessary. Too much water may result in anaerobic condition.**

Proper layering of the recipe will ensure appropriate heat for composting the mortalities in about 14 days. To begin, place 6 to 12 inches of litter or manure, followed by a 6-inch layer of loose straw to provide aeration, followed by a layer of dead birds. Depending on the moisture content of the manure or cake, water may or may not be added. Repeat this layering process until the pile or bin is full (see Fig. 4).

Leave 6 to 8 inches of space between the edges of the dead bird layer and the wooden wall of the composter. This space allows air movement around the pile and keeps carcasses nearer to the center of the pile, where the heat is highest. Do not stack dead birds on top of each other. They may be adjacent to one another, even touching, but they must be arranged in a single layer. Spread litter or manure and straw as evenly as possible.

▼ **Foundations.** An impervious, weight-bearing foundation or floor, preferably of concrete, should be provided under primary and secondary composting vessels or bins. Experience has shown that after frequent loading and unloading activities, dirt or gravel tends to become rutted and pot-holed. A good foundation ensures all-weather operation, helps secure against rodent and animal activity, and minimizes the potential for pollution of surrounding areas.

▼ **Building Materials and Design.** Pressure-treated lumber or other rot-resistant materials are necessary. A roofed composter ensures year-round, all-weather operation, helps control stormwater runoff, and preserves composting ingredients at the desired moisture content. Adequate roof height is also needed for clearance when using a front-end loader. The amount of rain that is blown into the composter can be minimized by the addition of partial sidewalls or curtains and guttering along the roof.

Thus, the key requirements for a mortality composter are good management; a properly sized, properly located facility; easy access; and a well-constructed, roofed structure. Following these regulations will result in a mortalities management system that is nonpolluting and capable of producing a valuable by-product.

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Rendering — A Disposal Method For Dead Birds

Rendering — the process of separating animal fats, usually by cooking, to produce usable ingredients such as lard, protein, feed products, or nutrients — is an ancient waste management process. It is also an excellent way to recycle dead birds. We are now able to reclaim or recycle almost 100 percent of inedible raw poultry material through rendering techniques.

Until recently, the animal protein in meat and bone meal residues was considered a waste of the rendering process; it was usually discarded, though it could sometimes be used as a fertilizer. Now rendering plants pick up or receive about 91 million pounds of waste annually to supply 85 percent of all fats and oils used in the United States. They also export 35 percent of the fats and oils used worldwide. Rendering operations provide a vital link between the feed industry and the poultry grower and help us control odor and prevent air and water pollution.

Rendering has not always been widely practiced as a poultry mortality management technique because

- dead birds may carry disease-causing organisms;
- suitable facilities for rendering have not always been available; and
- it can be difficult to keep the carcasses suitable for rendering.

Thus, dangers associated with the routine pick up and delivery of the carcasses to the rendering plant have been perceived as a threat to avian health and the environment.

Rendering's great advantage as a management technique is that it removes mortalities from the farm and relieves the grower of environmental concerns related to other methods of disposal. It may also provide some economic return. Therefore, as concerns for nutrient losses and water quality increase, producers and buyers of poultry products are experimenting with new techniques for delivering poultry mortalities to rendering plants as part of their mortalities management planning.

A major disadvantage of rendering as it is usually perceived is that disease may be carried back to the poultry farm by the vehicles or containers used to convey the dead birds to the rendering plant. Appropriate management and handling techniques can alleviate this difficulty.

Holding Methods

Raw or fresh poultry mortalities that are destined for a rendering plant must be held in a leak-proof, fly-proof container, and they must be delivered to, or be picked up by, a rendering company within 24 hours of death. All mortalities must be held in a form that retards decomposition until they are collected.

Freezing or Refrigeration, A New Holding Technique

Some producers are experimenting with a technique that combines on-the-farm freezing or refrigeration and the rendering process to determine whether freezing can be an effective way for growers to hold dead birds until they can be rendered. Large custom-built or ordinary commercial freezer boxes are being used to preserve dead birds until they can be picked up and delivered to the rendering plant. Custom-built boxes or units are usually free standing with self-contained refrigeration units designed to operate at temperatures between 10 and 20 °F.

Ideally, these freezer units will have no environmental or health impacts. The smaller ones are designed to allow the immediate removal of the carcasses from the growers; the larger ones, to hold the birds frozen until the box is full or otherwise scheduled for delivery to the plant.

Large domestic freezers will hold about 250 to 300 pounds of dead birds. Specifically designed boxes can handle 1,600 to 2,000 pounds of dead birds and are easily loaded through various door arrangements. They must also be sealed against weather and air leakage. The grower can load the freezer each day — once is a minimum. Putting the birds in the freezer in a single layer helps ensure that all the carcasses are properly refrigerated or frozen.

Fresh unfrozen carcasses are added to the box as the top layer. The temperatures are set to allow the product to be completely frozen within 24 hours. Check the temperature gauge at each loading. Overloading may prevent the total freezing of the carcasses.

The boxes can be emptied at the end of each growing cycle or as needed. The rendering plant can send a truck to the farm, or the grower may deliver the unit to the plant. Boxes or containers are picked up (using a forklift or front-end loader) and emptied. The freezer boxes open from the top, bottom, or sides for easy access and are then resealed. The refrigeration unit never leaves the farm, only the container holding the dead birds is removed or emptied. Freezer units are expected to last roughly 10 years. They operate on energy efficient circuit boxes with an operating cost of about $1.50 per day.

So far, the cost of freezing as a collection method is related to the cost of energy; its potential for generating income is not yet known. The product is processed at a rendering plant. Although some companies have already made an investment in these units, other growers should be able to recoup the costs of freezer boxes and product transportation. Transfer of pathogens or harmful microorganisms between farms has not been found to be a problem with this method of collection. Additional research is needed to fully explore this management option and any pathogenic problems that may be perceived in it; however, its proponents stress its usefulness as a way to reduce or eliminate potential pollution and improve conditions on the farm.

Fermentation

Fermentation procedures have been explored to determine whether they can contribute to a biologically secure and environmentally safe method of holding poultry carcasses until their nutrient components can be recovered in a form suitable for reprocessing and refeeding.

Fermentation is, in fact, a way to safely dispose of poultry mortalities, but it also keeps them on-site until the end of the growing cycle or until sufficient volume is attained for delivery to a rendering plant. Fermentation mixes the mortalities and a fermentable carbohydrate, such as sugar, whey, ground corn, or molasses.

The fermentation process produces organic acids that lower the pH of the mixture. The acidity of fresh tissue is near neutral (pH equals 6.3 to 6.5), while the acidity of the silage is 4.0 to 4.5. Thus, the activity of anaerobic bacteria (Lactobacillus, which are found naturally in poultry) converts the sugars into lactic acid and lowers the pH to less than 5.0, thus inactivating the pathogenic microorganisms in the carcasses and preserving the organic materials.

In the experiments presently underway, it has not been necessary to use any bacterial inoculant in the mixture. The fermented product is incubated anaerobically in airtight containers where it can be safely stored for several months — that is, until the amount of the product suffices to warrant the cost of transportation to the rendering plant.

Acid Preservation

Preserving foodstuff by acidification has been a widespread practice in agriculture. This method of preserving dead birds is the same as the fermentation process except that propionic, phosphoric, or sulfuric acid is added to the poultry carcasses, which are kept in an airtight, plastic container. Sulfuric acid may be preferred because it (1) retards spoilage, (2) excellently preserves the carcass, and (3) is relatively low in cost.

Carcasses can be punctured with a blunt metal rod rather than placed through a grinder. Punctured carcasses can be separated from the acid solution without the accumulation of sludge in the holding container.

The product resulting from lactic acid fermentation and acid preservation reduces the transportation costs associated with rendering by 90 percent. What is more important, however, is that these processes eliminate the potential for transmitting pathogenic organisms into the rendered products or environment. Accurate costs of fermentation and preservation are limited because most of the work has been through research. It is estimated, however, that costs will range from three to four cents per pound of dead birds.

In an expanding poultry industry, the production of manure and mortalities will only increase. Producers should contact the renderers in their area to determine which holding and transportation methods are acceptable, and they must increase their search for safe, cost-effective disposal and reuse methods. Every possible safe method should be explored until each grower determines the method most compatible with his or her situation and management abilities. Rendering, like composting, adds value to the end product.

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Site Selection For The Poultry Farmstead

Site selection and general farmstead planning are important elements in subsequent profitability and ease of animal waste management handling. Each site is, of course, unique, but some general environmental and safety considerations apply to all sites. Besides the visual impact, the first considerations are air quality (dust and odor control), the movement and quality of the water (drainage and supply), and availability of sufficient land for handling waste production. Site selection is also an appropriate beginning for establishing a good neighbor policy.

A good location will help you minimize potential problems with odor, rats, flies, beetles, and mice. Locating the poultry house conveniently near the farm residence is useful; but the location should also be attractive, or the house should be shielded (not visible) from the road, especially if it is near a property line. Building a vegetative windbreak or fence will not only help the operation's appearance, it will also reduce dust and odors that might create a nuisance, or the perception of a nuisance, among your neighbors. If the house is sited within an adequate windshed, many potential air quality problems can be avoided with little on no adverse effect on the community (see Fig. 1).

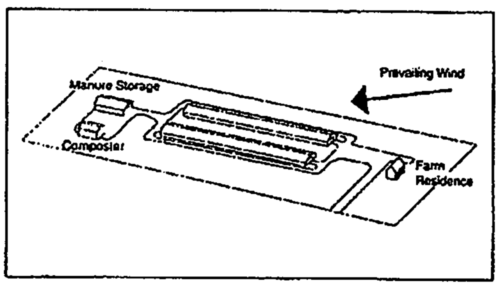

Figure 1.—Siting of a typical broiler operation.

Soil drainage (both surface and subsurface) is likewise an important consideration. A site on relatively high ground with adequate drainage can help prevent flooding, road wash outs, wet litter, and disease. Good drainage coupled with an appropriate use of gutters and grading around the outside of the building will direct runoff away from the production facility and family home. Soil drainage helps ensure access to the facility at all times on all-weather roads. It also helps secure a safe drinking water supply.

Subsurface drainage is also important to prevent excessive nutrients or other possible contaminants from entering the groundwater. In the manure storage area, a barrier between the manure and the ground is needed, such as a plastic tarp under the gravel or concrete base of the structure. Within the house itself, the removal of cake and wet litter should be planned; waterers should be inspected for leaks; and stirring, air drying, and ventilation should be part of standard operating procedures. Foundation drains or footing drains can also be added to remove any subsurface water that might otherwise enter the house.

Manure Storage Sites

Manure storage sheds, stacks, or windrows should be convenient to the poultry house, but distant enough to reduce disease transmissions between flocks or houses. A distance of 100 feet is reasonable. Storage structures are usually 40 feet wide with a 14-to-16-foot clearance.

The length varies depending on the amount of manure to be stored. Many of these structures are three-sided — a rectangle with one end open. The interior wall should be strong enough to withstand the weight of piled manure and the force of front-end loaders.

The site for a stack or windrow should be properly prepared before manure is laid down. If the storage time exceeds one month, a pad must be available, and the stack or windrow should be covered to reduce flies and odor problems. Manure stored on the bare earth must be completely removed to avoid creating an area in which high salinity and nitrate-nitrogen are a potential for groundwater contamination.

Dead Poultry Disposal

In the past, poultry mortalities were simply buried on site, but this disposal method is no longer feasible and is, in some places, illegal. Composting is one of several alternative methods that use this resource economically; it also helps protect water quality. For composting to work effectively, however, an appropriate structure is necessary. This structure can be conveniently attached to the manure storage facility. Refer to the appropriate fact sheets on manure storage and poultry mortality management for additional material on these topics.

The Farm*A*Syst Assessment Program

A new program that is helping to prevent water pollution in rural America is called Farm*A*Syst, the Farmstead Assessment System. It is a voluntary, farmstead or rural resident pollution risk assessment, designed to help rural residents become knowledgeable about water pollution risks and to help them develop an action plan to reduce the risks identified by the system. It may also be a useful tool for site selection and general farmstead planning.

The Farm*A*Syst program addresses nutrient contamination, water well design and location, waste and fertilizer storage, septic systems, dead bird disposal, pesticide and petroleum storage, household and farmstead hazardous waste and waste disposal, and microorganism contamination of well water. Growers can learn more about this program and how they can participate in it by contacting the National Farm*A*Syst Staff, B142 Steenbock, 550 Babcock Drive, University of Wisconsin, Madison, WI 53706 (phone 608/262-0024); or the USDA Soil Conservation Service or Cooperative Extension Service offices. Farm*A*Syst is jointly funded by the USDA Soil Conservation and Cooperative Extension Services, and the U.S. Environmental Protection Agency.

Conclusion

Proper siting and design of a poultry facility is important to the economy and success of the whole operation. It prevents problems before they arise, thus saving the grower money, time and worry, and best of all, it protects the environment and community from serious problems or distressing nuisances.

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Air Quality and Its Management

The Clean Air Act of 1970 provided for uniform air quality standards and control of emissions from existing facilities. It also prohibited the construction of new facilities that violate or interfere with federal or state regulations for air quality standards. Although many of the private citizen complaints and civil suits brought against livestock and poultry operators are because of odor problems, many of the states' air quality requirements have been established as a direct result of federal legislation. The odor (and sometimes dust) problems derived from poultry operations are associated with improper or mismanaged burial pits, emissions from incinerators, and land applications of poultry waste.

The Clean Air Act Amendment of 1990 (Pub. Law 101-549) also contains provisions of importance to producers of agricultural products. Because its goals are to reduce emissions that cause acid rain and to protect stratospheric ozone, ammonia volatilization from animal and other agricultural operations will most likely come under increased scrutiny and possible control. Some states are starting to request atmospheric ammonia test results on air samples taken at the property lines of animal operations.

Methane emissions from "rice and livestock production" and from "all forms of waste management . . . including storage, treatment, and disposal" are mentioned in the 1990 law as being of concern with regard to ozone depletion. These sources and others, both nationally and internationally, are to be evaluated by EPA jointly with the secretaries of Agriculture and Energy, and control options will be developed that can be used to stop or reduce growth of methane concentrations in the atmosphere.

Poultry Production Facilities and Air Quality

Poultry production facilities can be the source of gases, aerosols, vapors, and dust that can, individually or in combination, create air quality problems. These problems include

- nuisance odors,
- health problems for poultry in confined housing,
- deadly gases that can affect poultry and humans, and
- corrosion.

A variety of gases are generated during the decomposition of poultry wastes. Under aerobic conditions, carbon dioxide is the principal gas produced; under anaerobic conditions, the primary gases are methane and carbon dioxide. About 60 to 70 percent of the gas generated in an anaerobic lagoon or pit is methane and about 30 percent is carbon dioxide. Trace amounts of more than 40 other compounds have been identified in the air exposed to degrading animal waste, including mercaptans (the odor generated by skunks and the smell introduced in natural gas are in the mercaptan family), aromatics, sulfides, and various esters, carbonyls, and amines.

Methane, Carbon Dioxide, Ammonia, and Hydrogen Sulfide

The gases of most interest and concern in poultry nutrient management are methane (CH_4), carbon dioxide (CO_2), ammonia (NH_3), and hydrogen sulfide (H_2S). The following paragraphs summarize the most significant characteristics of these gases.

OTHER ENVIRONMENTAL ISSUES

▼ **Methane.** Methane, a flammable gas, is a possible source of energy on the farm. Because methane is also explosive, extreme care is required when attempting to generate and capture this gas for on-farm use.

▼ **Carbon Dioxide.** Carbon dioxide can be an asphyxiant when it displaces normal air in a confined facility. Because CO_2 is heavier than air, it remains in a tank or other well-sealed structure, gradually displacing the lighter gases. With high-density housing, gas and particulate levels may increase, and control becomes more difficult. Carbon dioxide increases substantially with the larger number of poultry producing CO_2, as compared with earlier low-density housing. Continued monitoring of temperature, air removal rate, and manure moisture content is required to maintain proper carbon dioxide concentrations.

▼ **Ammonia.** Ammonia is primarily an irritant and has been known to create health problems in animal confinement buildings. Irritation of the eyes and respiratory tract are common problems from prolonged exposure to this gas. It is also associated with soil acidification processes.

Ammonia concentration in broiler houses has increased in the past few years. The primary reason is that ventilation rates are reduced to conserve heat in the winter months. Research also shows that dust particles serve as an ammonia transport mechanism, so over-ventilation to the outside may lead to odors near the house and overly dry litter inside the house.

Ammonia concentration increases with increasing pH, temperature, and litter moisture content. It is desirable to maintain litter moisture in a production house below 30 percent for ammonia control. Studies indicate that ammonia increases bird susceptibility to Newcastle disease and decreases feed intake and egg production.

▼ **Hydrogen Sulfide.** Hydrogen sulfide is deadly. Humans and farm animals have been killed by this gas after falling into or entering a manure tank or a building in which a manure tank was being agitated. Although only small amounts of hydrogen sulfide are produced as compared to other major gases, this gas is heavier than air and becomes more concentrated over time.

Hydrogen sulfide has the distinct odor of rotten eggs. Hydrogen sulfide deadens the olfactory nerves (the sense of smell); therefore, if the smell of rotten eggs appears to have disappeared, this does not indicate that the area is not still contaminated with this highly poisonous gas. Forced-air ventilation or an exhaust system helps prevent gas poisoning. Otherwise, evacuate the area until the gas can be removed.

Where to Go for Help

Information on achieving air quality standards and managing the air quality problems of poultry production facilities is available from the U.S. Department of Agriculture, U.S. Environmental Protection Agency, and the Department of Energy. Poultry associations and state water quality agencies can also help.

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Preventing Fires in Manure/Litter Storage Structures

Hundreds of poultry manure/litter storage structures have been built as a component of a total waste management program on the poultry farmstead. Storage facilities help prevent the possibility of water pollution and provide flexibility in the timing of land applications. They also protect this resource from the weather and wildlife so that it can be used as a cattle feed.

Manure piles will generate heat, however, and care should be taken to prevent fires in the storage facility. Spontaneous combustion in a litter stack is possible, probably as a result of the buildup of combustible methane or the storage of wet and dry litter. Fires may also occur if the manure is stacked too close to wooden walls that may ignite when the temperature in the litter reaches the wood's flash point. The exact causes of litter storage fires are difficult to know, but good management principles will help protect the litter.

Methane Production

Anaerobic bacteria generate about 50 to 65 percent methane, about 30 percent carbon dioxide, and a smaller percentage of other gases. Therefore, if the moisture content of stored litter is more than 40 percent in a stack with little or no oxygen, then conditions are right for anaerobic bacteria to grow and methane to result. Unvented landfills have the same problem. Methane's specific gravity is less than air, however. If the stack has adequate pore spaces (or the landfill has ventilation pipes), the methane will escape into the atmosphere.

High moisture levels in stored litter help create the potential for fires, as does layering the manure (putting new litter on top of old litter). Compacting the litter will trap heat in the pile, and failure to provide an adequate ratio of surface area to volume can also create problems.

Tips for Fire Prevention

The following guidelines will help prevent fires in storage facilities:

- Keep the litter dry and do not stack it too near the open end of the building (methane is flammable in air).
- Do not compact moist cake or mix it with dry litter; and do not stack cake or dry litter higher than 5 feet or store it against the wood.
- Do not compact the dry litter, since compacting creates anaerobic conditions and prevents the natural venting of methane.
- Do not cover moist litter but allow the open litter to vent naturally.
- Monitor the resources in your storage facility regularly, and remove any materials that have temperatures greater than 180 °F. If the temperatures exceed 190 °F, notify the fire department and prepare to move the material. Emptying the storage area will bring the litter out into the air, so precautions must be taken against a fire occurring at this time.

It is a good idea not to store expensive equipment in the litter storage facility.

If you are storing dry litter for later use as a cattle feed, cover it with polyethylene. This technique will suppress the temperature buildup and reduce the production of bound nitrogen, a form of protein that cattle are unable to digest.

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Other pages in this handbook contain more detailed information on these subjects. Permission is hereby granted to producers, growers, and associations serving the poultry industry to reproduce this material for further distribution. The Poultry Water Quality Consortium is a cooperative effort of industry and government to identify and adopt prudent uses of poultry by-products that will preserve the quality of water for everyone.

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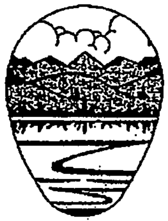

Treatment Lagoons and Ponds

Manure in shallow pits (from caged layers) can be flushed out once a day or scraped out dry every one to three days. Flushed manure can then be transferred to storage by gravity or with a pump. Semisolid or liquid manure can be stored in below or above ground ground storage tanks, steel storage tanks, or earthen basins. Thus, lagoons are a type of earthen basin used for waste storage; however, they can also be used as manure treatment systems for converting the organic matter in animal wastes into more stable products. Lagoons have even been used as digesters to convert large masses of waste into gases, liquids, or sludge. Aerobic and anaerobic lagoons work with bacteria to decompose the dissolved solids in animal waste.

Lagoons became a somewhat popular component of waste management systems during the 1970s when the interest shifted from simply using waste for fertilizer in land applications to treating the waste to produce a more convenient waste management system overall.

Anaerobic bacteria in animal waste (i.e., bacteria that live in animal intestines) cannot work in the presence of oxygen. Aerobic bacteria, on the other hand, must have oxygen; therefore, anaerobic lagoons are deep and airless; aerobic lagoons are spread over a large surface area, take in oxygen from the air, and support algae.

The advantages of lagoons are that they are easy to manage, convenient, and cost-efficient. Storage and land application can be handled more opportunely if the grower has a lagoon, and labor costs and operating costs are slight after the initial investment. In general, anaerobic lagoons do not require much space, and they provide storage and disposal flexibility.

Other factors, however, must also be considered. Lagoons are a source of odors and nitrogen losses and may require frequent sludge removal if they are undersized. Groundwater protection may be difficult to secure, and if mechanical aeration is used, energy costs must be included in the accounting. Proper management is essential for lagoon maintenance and operation.

Aerobic Lagoons

The design, shape, size, capacity, location, and construction of the lagoon depends on its type. Aerobic lagoons require so much surface area (to maintain sufficient dissolved oxygen) that they are an impractical solution to most waste management problems. They may require 25 times more surface area and 10 times more volume than an anaerobic lagoon. Nevertheless, some growers may consider using an aerated lagoon — despite its expense — if they are operating in an area highly sensitive to odor.

Some of the sizing difficulty can be solved by using mechanical aeration — by pumping air into the lagoon — but the energy costs for continuous aeration can be high. Aerobic lagoons will have better odor control, and the bacterial digestion they provide will be more complete than the digestion in anaerobic lagoons.

Lagoon design and loading specifications should be carefully followed and monitored to increase the effectiveness of the treatment. No more than 44 pounds of biological oxygen demand (BOD) effluent should be added to the lagoon per day per acre. The lagoon should have sufficient depth so that light will penetrate the 3 or 4 feet of water. Effluents from the lagoon should be land applied to avoid long-term ponding and to make economical use of the nutrients that remain in them.

Anaerobic Lagoons

Anaerobic treatment lagoons are earthen basins or ponds containing diluted manure that will be broken down or decomposed without free oxygen. In the process, the organic components or BOD in the manure will be liquified or degraded naturally. Anaerobic lagoons must be properly designed, sized, and managed to be an acceptable animal waste treatment facility.

Liquid volume rather than area determines the size of anaerobic lagoons. The lagoon should accommodate the design treatment liquid capacity and the amount of wastewater to be treated; it should also have additional storage room for sludge buildup, temporary storage room for rain and wastewater inputs, extra surface storage for a 25-year, 24-hour storm event, and at least an additional foot of freeboard to prevent overflows.

The design criteria for anaerobic lagoons are based on the amount of volatile solids to be loaded each day. The range is from 2.8 to 4.8 pounds of volatile solids per day per 1,000 cubic feet of lagoon liquid. The amount of rain that would collect in a 24-hour storm so intense that its probability of happening is once in 25 years requires at least 5 to 9 inches of surface storage.

To protect the groundwater supply, lagoons should not be situated on permeable soils that will not seal, on shallow soils, or over fractured rock. Nor should mortalities be disposed of in lagoons; in fact, screening the wastes before they enter the lagoon helps ensure complete digestion and the quality of the wastewaters for land applications. If the site's topography indicates a potential for groundwater contamination, then any earthen basin should be lined with clay, concrete, or a synthetic liner.

New lagoons should be filled one-half full with wastewater before waste loading begins. Planning start up in warm weather and seeding the bottom with sludge from another lagoon helps to establish the bacterial population. Because bacterial activities increase in high temperatures, lagoons, in general, work best in warm climates. Manure should be added to anaerobic lagoons daily, and irrigation (drawdown) should begin when the liquid reaches normal wastewater maximum capacity. The liquid should not be pumped below the design level treatment, however, because the proper volume must be available for optimum bacterial digestion.

Drawdown (that is, the lagoon liquid) can be used for land applications guided by regular nutrient management planning and sampling of the lagoon liquids and soils to ensure safe and effective applications. When sludge accumulation diminishes the lagoon's treatment capacity, it, too, can be land applied under strictly monitored conditions.

Secondary lagoons are often needed for storage from the primary lagoon. Using a secondary lagoon for irrigation also bypasses some of the solids picked up in the primary lagoon. The size of secondary lagoons is not critical.

Information and technical assistance and some cost-share programs are available for producers who determine that a lagoon system should be part of their resource management system. The USDA Soil Conservation and Cooperative Extension Service offices can provide additional assistance.

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OTHER ENVIRONMENTAL ISSUES

Other pages in this handbook contain more detailed information on these subjects. Permission is hereby granted to producers, growers, and associations serving the poultry industry to reproduce this material for further distribution. The Poultry Water Quality Consortium is a cooperative effort of industry and government to identify and adopt prudent uses of poultry by-products that will preserve the quality of water for everyone.

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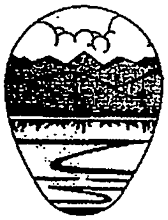

Controlling Struvite Buildups

Magnesium ammonium phosphate, sometimes called struvite, is a grayish-white crystalline salt that builds up on the internal pump and piping surfaces used for lagoon liquid recycling. It usually appears on metallic surfaces but also on plastics. Steel, cast iron, bronze, and brass are equally susceptible.

Struvite usually builds up on the internal pump components first, then moves outward to the discharge pipes. It often occurs at pipe joints, elbows, valves, or imperfections because grit and solids tend to lodge at these points, providing a base for the salt to grow. Predicting struvite is difficult because its cause is not well known. Design, maintenance, and management techniques have been researched that can reduce the buildup to acceptable levels.

Pumping and Piping System

Use only high-quality, low-pressure, self-priming centrifugal or submersible pumps. They should not be oversized in relation to the piping network, and should perhaps be on a timer. The suction pipe should also be large enough to prevent pump cavitation. Normally the suction pipe diameter should be one size larger than the discharge pipe. Locate the pump close to the high-water level to minimize suction lift. Replace fine mesh suction intake strainers with wire screens or baskets of 1-inch mesh or larger. The diameter should be at least five times the diameter of the suction pipe. Struvite will also build up on the screens.

Use nonmetallic pipes and fittings. Pipes should be large enough to maintain flow velocities between 3 to 5 feet per second; the minimum pipe diameter at any point except at the immediate discharge point should be 1.5 inches. Sharp pipe bends (elbows and tees) should be avoided. Instead, use flexible plastic pipe and long sweep elbows for the direction changes. The system (pumps and piping) should have sufficient capacity to work only one-half to two-thirds of the time, and piping systems not in continuous use should be drained between pumping events.

Electrostatic Charges

Stray voltage is also believed to contribute to struvite. Direct grounding of the pump housing can discharge any static charges. A metal rod should be placed 10 to 12 feet into the moist soil near the lagoon's edge, and cable connections at the ground rod and pump should be checked periodically for corrosion.

Lagoon Management

Lagoons should be properly sized. New ones should be charged at least half full of water before startup, and the liquid level should be brought up to design levels as soon as possible. Rainfall during normal years dilutes lagoon liquid while extended periods of hot, dry weather increase nutrient and salt levels and the rate of salt buildup in recycling systems. Flushing with fresh water or irrigating a portion of the lagoon contents may help.

Acid Cleaning

Salts can be dissolved with dilute acid treatments. Several doses followed by flushing the spent acid solutions will be needed to treat heavy buildups. A more thorough and more costly method is to install an acid recirculation loop. Use a 150-gallon acid-resistant tank as the reservoir. You will need enough solution to fill the pipe length and some in reserve to keep the recirculation pump primed. Use the accompanying table to determine how much acid you will need.

Table 1.—Amount of solution needed for acid cleaning using an acid recirculation loop.

DIAMETER OF PIPE, IN INCHES	SOLUTION NEEDED PER FOOT OF LENGTH, IN GALLONS
1.0	0.06
1.5	0.13
2.0	0.20
2.5	0.29
3.0	0.43
4.0	0.70
6.0	1.53

To reduce the size of the tank, isolate sections of the line with valves and circulate the acid through only one section. The flush pump suction is switched from the lagoon and connected to the bottom of the acid tank with a quick-connect coupling. A 1-inch line returns acid from the end of each treated pipe section to the tank.

Hydrochloric acid can be purchased at most chemical supply houses or paint stores. Dilute the acid with water on a 1 to 9 ratio — 1 gallon acid to 9 gallons of water. Use caution. Mixing acids with water is a hazardous operation. Partially fill the tank with water, then add the acid slowly to the water. Eye protection is essential, and heat will be generated. To treat heavy struvite buildups, recirculate the mixture overnight and count on using the mixture only once. Spent acid may be dumped into the lagoon. Acids currently cost about $14 for a 15-gallon drum or about $33 for a 50-gallon drum. Deposits on the drums are $25 and $50, respectively.

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Protection Against Pests, Predators, and Darkling Beetles

Pests, often called vectors because they may be a point of entry for disease or other nuisances in the poultry house, are an aspect of waste management that should not be overlooked. Vectors can be either living or nonliving carriers of disease. Especially troublesome on the poultry farm are house flies, rats, and darkling beetles. Wildlife, especially feral dogs and coyotes, must also be controlled. Having proper waste management facilities and maintenance procedures on the farm will contribute to productivity, nutrient management, and environmental safety. A cost-effective and safe pest control system is essential.

Uncontrolled pests cause irritation to birds and workers, carry poultry disease pathogens, increase mortality, lower carcass grades and production, damage building materials, and interfere with feed conversion. In addition, and if they did nothing else, poultry pests must be carefully controlled because they can migrate from litter to nearby residences, where they may become a serious nuisance among the neighbors.

Flies

Moist manure is not only a threat to surface and groundwaters; it is also an ideal breeding ground for flies. Caged layer operations are most susceptible to this problem, followed by breeder farms and, occasionally, broiler farms. Wherever poultry houses are susceptible to flooding, or litter is stored outdoors, the potential exists for fly-control problems.

Flies, which generally become active in the early spring (mid-March in many areas), have four stages of development: egg, larva, pupa, and adult. Most generations require about two weeks to develop. Females will produce 120 to 150 eggs in three or four days, and hatching occurs between eight and 24 hours later. House flies can complete their entire life cycle in as few as seven days; therefore, many of these 150 flies will also breed within a few days. Twenty to 30 generations in a fly season is not unusual. As many as 1,000 flies can develop in a single pound of suitable breeding material.

The actual rate of development depends on the temperatures and moisture levels in the breeding area. Since fresh manure is about 75 percent moisture, and flies breed in areas containing 75 to 80 percent moisture, poultry litter should be kept as dry as possible. Leakproof waterers should be installed and maintained in good condition. Broken eggs and mortalities among the flock should be cleaned up immediately.

Manure should be removed from the house every four to seven days during hot weather. After removal, it must be stored and used properly to achieve fly control. If manure can be dried quickly or immediately liquified, it will not become a breeding ground for flies. During land applications, poultry manure should be spread thinly to promote drying. If fly larvae are in the manure, then incorporating it into the soil as quickly as possible will help break the fly development cycle.

Under certain conditions, insecticides may be used to control adult flies in barns and poultry houses. But these products should be reserved for critical times when the management system breaks down, because flies quickly develop resistance. Insecticide applications may be regulated in some states and should be handled carefully to minimize any harmful effects associated with toxic ingredients.

Rats and Mice

Voles, field mice, and cotton rats are not usually the source of problems for poultry growers. Norway rats and roof rats, however, are two non-native species of rats that can be troublesome — and they proliferate rapidly. A pair of rats will produce six to 12 young in 21 days — and each of these becomes sexually mature in three months. A single pair of rats, if they find food, water, and shelter, can produce a colony of 640 rats in a year.

Poultry houses provide everything the rats need: food, water, and shelter. Norway or wharf rats usually nest under buildings and concrete slabs and in garbage dumps. They are great burrowers and may have an extensive system of burrows under the poultry house, with several escape routes. They eat anything but prefer nuts, grains, meats, and some fruits. They can easily find meats and grains in the poultry house.

Roof or black rats are more aerial than Norway rats. They enter buildings from the roof or utility lines. They usually live in trees, so access to the poultry house is easy: up the walls, across vines, along pipes. Exterior walls should be hard, flat surfaces, and all entrance holes should be plugged up. Rats can make themselves "paper thin" to come in under doors and through holes as small as one-half inch in diameter.

The best rat control program is proper resource management, maintenance, and sanitation; but the food supply in the poultry house makes rat occupation probable. Some chemical controls or rodenticides may, and probably should be, added to your control program. To administer rat poison effectively, first know how many rats you are dealing with; then, establish bait stations near the walls in areas of rodent activity.

To determine how many rats are in the poultry house, observe the area at night as well as in the daylight. Rats are nocturnal; if you see no rats in the day or at night, there probably are not many around. If you see old droppings or gnawed areas, no rats during the day, and only a few at night, rats are probably present in medium numbers only. Finally, if you see fresh droppings and tracks, some rats during the day, and three or more at night, large numbers are probably present.

To control the infestation, use single or multiple doses of a rodenticide in the bait stations. Avoid making the rats sick; if they get sick and do not die, they will become bait-shy and not eat the poison. Place the bait stations appropriately and protect them from moisture, dust, and weather to encourage the rats to eat from these stations. Rats, like many animals, prefer fresh food.

Because rats are colorblind and have poor eyesight, rodenticides can be marked for safety. If other conditions make poisons inadvisable, rats can be trapped with common snap traps, glue boards, or in live traps.

Darkling Beetles

Known as litter beetles, lesser mealworms, or "black bugs," the darkling beetle (*Alphitobius diaperinus*) is found in large numbers in poultry houses, in the woods, and around feed bins. These black or reddish-brown beetles are troublesome in turkey and broiler production because deep litter and open-floor housing provide an ideal habitat in which the beetles can survive and reproduce.

The total effect of darkling beetles on poultry production is not known. They may be more problematic as a nuisance than as a vector (carrier of disease). However, beetles are thought to harbor a number of disease organisms — for example, fowl pox, *E. coli*, *Salmonella* spp., Newcastle disease, and avian leukosis — and to be involved in the transmission of the causative organism for Marek's disease, although immunization against Marek's disease is now available. Darkling beetles are also an intermediate host for poultry tapeworms and cecal worms. If they are in litter that is land applied, their possible effects on wildfowl must be considered.

An undisputed second concern related to the darkling beetle is that they can damage the insulation in poultry houses. Larvae bore into the insulation to find safe places to pupate. But adult beetles who eat the pupae soon enlarge the larval tunnels in their search for an easy meal. Birds and mice then claw at the insulation to get at the adult beetles, larvae, and pupae. In a severe darkling beetle infestation, as much as 25 percent of the insulation can be lost in a single year.

Another potential problem arises if infested litter is spread on crops. Adult beetles may migrate from the field into nearby residences; the result can be a nuisance complaint to the health department — and sometimes lawsuits.

Temperature and moisture affect the amount of time an insect needs to complete its life cycle. Temperatures between 60 and 100 °F and moisture levels above 12 percent are optimum for its survival. Food sources, decaying litter, an occasional bird carcass, and the absence of major predator and parasite complexes in the poultry house help the beetle population to increase.

The life cycle of the beetle takes 35 to 60 days to complete. The adult female lays eggs individually or in clusters at intervals of one to five days throughout her life cycle. The eggs hatch into tiny larvae after four to seven days and grow through five to nine stages, called instars. This period lasts for seven weeks; then the beetles pupate in cracks and crevices, in the soil and lower strata of the litter, and in building insulation. The pupal state lasts for seven to 11 days, after which a new adult emerges.

To manage darkling beetles effectively requires monitoring, cultural practices, and some insecticide applications. Treatment should be maintained regularly, even if beetle numbers are low. Individual beetles or larvae (100 or fewer) pose no problem; however, their presence indicates a need for continued monitoring, ideally on a weekly basis, from the time the birds are brought into the house until they are removed. Visual inspection is the best way to monitor the open-floored, deep litter house. The grower should look at litter, carcasses, cracks and crevices, equipment, and insulation at intervals of 30 to 40 feet throughout the house.

- Litter should be examined along walls, around support posts, and under brooder hoods and feeders. Dig down 1 to 2 inches in caked litter to look for small, early instars.
- Carcasses should be examined during daily collections. A large number of beetles on a large number of carcasses may point to a heavy infestation.
- Equipment and cracks and crevices are favorite beetle habitats. Be sure to check the framing joints and other cracks as well as the brooder guard, house dividers, drinkers, and feeders.
- Insulation in new houses should be checked for clusters of small holes along seams, in corners, at the eaves, and along the gable. Insulation board may also be discolored. If mice damage appears, look also for beetle tunnels. In older houses, it will be hard to distinguish between old and new beetle damage.

Trapping beetles is a second control method. Traps can be made using a 2-inch schedule 40 PVC pipe, a 10-to-12-inch section for each trap. Put a roll of corrugated cardboard (brooder guard) inside the pipe, and place six or so traps between the wall, feeder, and brooder locations from one end of the house to the other. To prevent the birds from moving the traps, stake the traps in place. Remove the cardboard and count the beetles on a weekly schedule. Their presence or a rapid rise in their number indicates a need for treatment.

Cultural methods for controlling beetles are nonchemical ways to reduce the pest population. Cold weather is the most effective measure, and proper litter handling is also an essential for good control. If the weather cooperates, open the house to the cold between flocks. If the temperature drops below 30 °F, all stages of the darkling beetle will die. As soon as the birds are moved, the grower can remove litter and litter cake from the poultry house. Darkling beetles will move to protected areas in the empty house within a few days; therefore, moving the litter before that time will more effectively control the beetle population.

Fresh litter that is applied to cropland should be incorporated to prevent any return of the darkling beetle. Stockpiled or composted litter should be turned every two weeks to promote enough heat to kill beetle eggs and larvae.

Although all insecticides registered as controlling darkling beetles will work, none controls the house for more than one flock. Therefore, a treatment program should be maintained year-round. Most products remain active about a week and are designed to be applied when the birds have been removed from the house. The best time for application is on the first day after the birds have been removed followed by cleanup immediately on the second day. Treating the house again — and its outside perimeter — just before the placement of a new flock, is also useful. Surface sprays, dusts, and baits are available for making these applications.

Beetles love temperatures between 70 and 90 °F; they are nocturnal and can be found everywhere. Seeing them during the day is a sure sign of infestation — of their presence in great numbers. Young chicks will eat them. Darkling beetles can fly up to one mile a night. If a million or so are taken from a house, 15,000 of those taken will return in the direction of the house from which they came. Approved insecticides are Rabon, Sevin, and boric acid compounds. Best control methods are careful cleanout and spraying.

Beetles cause reductions in feed conversions and weight gains, and possible disease. Under dry conditions, they will eat the flesh of dead or down birds, and at night crawl up the feathers of resting birds and bite the skin around the feather follicals. Bitten birds may have weeping skin lesions or pink and swollen areas around the feather follicals that resemble skin leukosis. The birds are forced to rest and wander all night instead of eating and sleeping as they would in properly managed houses.

Darkling beetles are a general nuisance because they are attracted by light; therefore, they will crawl out of the litter and move toward the light at night. Large numbers of beetles on or in houses create a negative public image and give rise to complaints against the broiler producer. To prevent migration, spray the pit walls and posts, or use well-sealed, angled, metal flashing attached to pit walls at posts and masonry frame wall joints.

Coyotes and Feral Dogs

Coyotes and feral dogs are opportunistic feeders. If they live in the area, their presence around a poultry house is not remarkable. They will kill the poultry for food, but they can easily be prevented from gaining access to the house. Complete confinement of the poultry is the best way to stop predation. Heavy wire should be used to cover all openings. Sanitation and the proper disposal of mortalities will cut down on the attraction of coyotes to the area.

Predator calling and shooting may be used in most states to harvest these animals. Predator calling is a mechanical device that attracts the animals within shooting range. Trapping is also an effective control method. Traps and trap sizes as well as hunting and trapping seasons may be regulated in some places. Leghold traps that do not harm the animal or traps with padded jaws may offer the best control in some situations.

Controlling animals and pests in poultry houses involves a combination of resource management, sanitation, and exclusion, and some special measures such as chemicals, hunting, or trapping.

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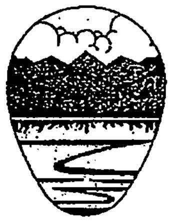

Constructed Wetlands

Agricultural runoff contributes about 60 percent of the nonpoint source pollution that threatens water quality in the rivers and lakes of the United States. Water that flows off the land after precipitation events picks up fertilizers and animal wastes that have been applied to the soil and deposits them in lakes and rivers.

If the runoff is uncontrolled, it causes soil erosion and the flow of high amounts of suspended solids, nutrients, pesticides, herbicides, and metals into the receiving waters. Flooding and the degradation of rivers, streams, and lakes are the consequence. Nonpoint source pollution can also threaten groundwater quality as the same pollutants leach through the soil.

Runoff can be controlled. Best management practices (BMPs) can be adopted as part of the poultry grower's operating procedure. For example, stormwater can be diverted from poultry houses and manure storage areas, and land applications can be made when no storms are predicted. In addition, the arsenal of BMPs now includes the use of natural or constructed wetlands for treating runoff and wastewater.

Functions of Wetlands

Wetlands are defined as transitional areas between the land and water. They support water-tolerant or aquatic plants, and their soils are saturated (waterlogged) or covered with shallow water for some part of the year. Bogs, swamps, marshes, and sloughs are types of wetlands.

Wetlands help improve water quality, store floodwaters, reduce erosion, and recharge groundwater. They are also habitat for wildlife and home to about one-third of our endangered species, though our focus is on wetlands for waste treatment. The treatment process involves complex physical, biological, and chemical interactions, but it can be simply described.

If surface runoff flows through wetlands before reaching open water, its progress will be slower here than in channelized flows over drier lands. Suspended solids will settle or filter out, and microorganisms will pick up the organics and nutrients in the water for food. Metals will settle into the soil and be absorbed by plants. Thus, pollutants in stormwater runoff can be reduced, cleansed, or transformed into harmless substances during the runoff's passage or treatment in natural or constructed wetlands. Most pollutants are transformed into basic elements, compost, or biomass.

The constructed wetland is the heart of the treatment system. It cleans wastewater by filtering and settling solids, decomposing organics, and adsorbing/absorbing other pollutants such as phosphorus and trace metals. The dissolved organic pollutants are removed by a complex group of microbes (bacteria, fungi, algae, and protozoa) that live in the wastewater and on plant and sediment surfaces. Since waste materials are food for most of these microbes, pollutants are gradually converted through complex food cycles into environmentally harmless by-products (gases that escape to the air and inert solids that stay in the system).

The primary purpose of wetland plants is to provide a place for these microbes to attach and grow. Generally, treatment effectiveness increases with plant density, which allows a larger quantity of attached microbes to exist within the system. The density of plants also affects flow hydraulics. Uniform flow is enhanced by uniform plant densities, but variable densities create short-circuiting which be regulated in some states and should be handled carefully to minimize any harmful effects associated with toxic ingredients.

Rats and Mice

Voles, field mice, and cotton rats are not usually the source of problems for poultry growers. Norway rats and roof rats, however, are two non-native species of rats that can be troublesome — and they proliferate rapidly. A pair of rats will produce six to 12 young in 21 days — and each of these becomes sexually mature in three months. A single pair of rats, if they find food, water, and shelter, can produce a colony of 640 rats in a year.

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To determine how many rats are in the poultry house, observe the area at night as well as in the daylight. Rats are nocturnal; if you see no rats in the day or at night, there probably are not many around. If you see old droppings or gnawed areas, no rats during the day, and only a few at night, rats are probably present in medium numbers only. Finally, if you see fresh droppings and tracks, some rats during the day, and three or more at night, large numbers are probably present.

To control the infestation, use single or multiple doses of a rodenticide in the bait stations. Avoid making the rats sick; if they get sick and do not die, they will become bait-shy and not eat the poison. Place the bait stations appropriately and protect them from moisture, dust, and weather to encourage the rats to eat from these stations. Rats, like many animals, prefer fresh food.

Because rats are colorblind and have poor eyesight, rodenticides can be marked for safety. If other conditions make poisons inadvisable, rats can be trapped with common snap traps, glue boards, or in live traps.

Darkling Beetles

Known as litter beetles, lesser mealworms, or "black bugs," the darkling beetle (*Alphitobius diaperinus*) is found in large numbers in poultry houses, in the woods, and around feed bins. These black or reddish-brown beetles are troublesome in turkey and broiler production because deep litter and open-floor housing provide an ideal habitat in which the beetles can survive and reproduce.

The total effect of darkling beetles on poultry production is not known. They may be more problematic as a nuisance than as a vector (carrier of disease). However, beetles are thought to harbor a number of disease organisms — for example, fowl pox, *E. coli*, *Salmonella* spp., Newcastle disease, and avian leukosis — and to be involved in the transmission of the causative organism for Marek's disease, although immunization against Marek's disease is now available. Darkling beetles are also an intermediate host for poultry tapeworms and cecal worms. If they are in litter that is land applied, their possible effects on wildfowl must be considered.

An undisputed second concern related to the darkling beetle is that they can damage the insulation in poultry houses. Larvae bore into the insulation to find safe places to pupate. But adult beetles who eat the pupae soon enlarge the larval tunnels in their search for an easy meal. Birds and mice then claw at the insulation to get at the adult beetles, larvae, and pupae. In a severe darkling beetle infestation, as much as 25 percent of the insulation can be lost in a single year.

Another potential problem arises if infested litter is spread on crops. Adult beetles may migrate from the field into nearby residences; the result can be a nuisance complaint to the health department — and sometimes lawsuits.

Temperature and moisture affect the amount of time an insect needs to complete its life cycle. Temperatures between 60 and 100 °F and moisture levels above 12 percent are optimum for its survival. Food sources, decaying litter, an occasional bird carcass, and the absence of major predator and parasite complexes in the poultry house help the beetle population to increase.

The life cycle of the beetle takes 35 to 60 days to complete. The adult female lays eggs individually or in clusters at intervals of one to five days throughout her life cycle. The eggs hatch into tiny larvae after four to seven days and grow through five to nine stages, called instars. This period lasts for seven weeks; then the beetles pupate in cracks and crevices, in the soil and lower strata of the litter, and in building insulation. The pupal state lasts for seven to 11 days, after which a new adult emerges.

To manage darkling beetles effectively requires monitoring, cultural practices, and some insecticide applications. Treatment should be maintained regularly, even if beetle numbers are low. Individual beetles or larvae (100 or fewer) pose no problem; however, their presence indicates a need for continued monitoring, ideally on a weekly basis, from the time the birds are brought into the house until they are removed. Visual inspection is the best way to monitor the open-floored, deep litter house. The grower should look at litter, carcasses, cracks and crevices, equipment, and insulation at intervals of 30 to 40 feet throughout the house.

- Litter should be examined along walls, around support posts, and under brooder hoods and feeders. Dig down 1 to 2 inches in caked litter to look for small, early instars.
- Carcasses should be examined during daily collections. A large number of beetles on a large number of carcasses may point to a heavy infestation.
- Equipment and cracks and crevices are favorite beetle habitats. Be sure to check the framing joints and other cracks as well as the brooder guard, house dividers, drinkers, and feeders.
- Insulation in new houses should be checked for clusters of small holes along seams, in corners, at the eaves, and along the gable. Insulation board may also be discolored. If mice damage appears, look also for beetle tunnels. In older houses, it will be hard to distinguish between old and new beetle damage.

Trapping beetles is a second control method. Traps can be made using a 2-inch schedule 40 PVC pipe, a 10-to-12-inch section for each trap. Put a roll of corrugated cardboard (brooder guard) inside the pipe, and place six or so traps between the wall, feeder, and brooder locations from one end of the house to the other. To prevent the birds from moving the traps, stake the traps in place. Remove the cardboard and count the beetles on a weekly schedule. Their presence or a rapid rise in their number indicates a need for treatment.

Cultural methods for controlling beetles are nonchemical ways to reduce the pest population. Cold weather is the most effective measure, and proper litter handling is also an essential for good control. If the weather cooperates, open the house to the cold between flocks. If the temperature drops below 30 °F, all stages of the darkling beetle will die. As soon as the birds are moved, the grower can remove litter and litter cake from the poultry house. Darkling beetles will move to protected areas in the empty house within a few days; therefore, moving the litter before that time will more effectively control the beetle population.

Fresh litter that is applied to cropland should be incorporated to prevent any return of the darkling beetle. Stockpiled or composted litter should be turned every two weeks to promote enough heat to kill beetle eggs and larvae.

Although all insecticides registered as controlling darkling beetles will work, none controls the house for more than one flock. Therefore, a treatment program should be maintained year-round. Most products remain active about a week and are designed to be applied when the birds have been removed from the house. The best time for application is on the first day after the birds have been removed followed by cleanup immediately on the second day. Treating the house again — and its outside perimeter — just before the placement of a new flock, is also useful. Surface sprays, dusts, and baits are available for making these applications.

Beetles love temperatures between 70 and 90 °F; they are nocturnal and can be found everywhere. Seeing them during the day is a sure sign of infestation — of their presence in great numbers. Young chicks will eat them. Darkling beetles can fly up to one mile a night. If a million or so are taken from a house, 15,000 of those taken will return in the direction of the house from which they came. Approved insecticides are Rabon, Sevin, and boric acid compounds. Best control methods are careful cleanout and spraying.

Beetles cause reductions in feed conversions and weight gains, and possible disease. Under dry conditions, they will eat the flesh of dead or down birds, and at night crawl up the feathers of resting birds and bite the skin around the feather follicals. Bitten birds may have weeping skin lesions or pink and swollen areas around the feather follicals that resemble skin leukosis. The birds are forced to rest and wander all night instead of eating and sleeping as they would in properly managed houses.

Darkling beetles are a general nuisance because they are attracted by light; therefore, they will crawl out of the litter and move toward the light at night. Large numbers of beetles on or in houses create a negative public image and give rise to complaints against the broiler producer. To prevent migration, spray the pit walls and posts, or use well-sealed, angled, metal flashing attached to pit walls at posts and masonry frame wall joints.

Coyotes and Feral Dogs

Coyotes and feral dogs are opportunistic feeders. If they live in the area, their presence around a poultry house is not remarkable. They will kill the poultry for food, but they can easily be prevented from gaining access to the house. Complete confinement of the poultry is the best way to stop predation. Heavy wire should be used to cover all openings. Sanitation and the proper disposal of mortalities will cut down on the attraction of coyotes to the area.

Predator calling and shooting may be used in most states to harvest these animals. Predator calling is a mechanical device that attracts the animals within shooting range. Trapping is also an effective control method. Traps and trap sizes as well as hunting and trapping seasons may be regulated in some places. Leghold traps that do not harm the animal or traps with padded jaws may offer the best control in some situations.

Controlling animals and pests in poultry houses involves a combination of resource management, sanitation, and exclusion, and some special measures such as chemicals, hunting, or trapping.

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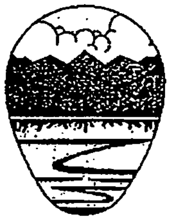

Constructed Wetlands

Agricultural runoff contributes about 60 percent of the nonpoint source pollution that threatens water quality in the rivers and lakes of the United States. Water that flows off the land after precipitation events picks up fertilizers and animal wastes that have been applied to the soil and deposits them in lakes and rivers.

If the runoff is uncontrolled, it causes soil erosion and the flow of high amounts of suspended solids, nutrients, pesticides, herbicides, and metals into the receiving waters. Flooding and the degradation of rivers, streams, and lakes are the consequence. Nonpoint source pollution can also threaten groundwater quality as the same pollutants leach through the soil.

Runoff can be controlled. Best management practices (BMPs) can be adopted as part of the poultry grower's operating procedure. For example, stormwater can be diverted from poultry houses and manure storage areas, and land applications can be made when no storms are predicted. In addition, the arsenal of BMPs now includes the use of natural or constructed wetlands for treating runoff and wastewater.

Functions of Wetlands

Wetlands are defined as transitional areas between the land and water. They support water-tolerant or aquatic plants, and their soils are saturated (waterlogged) or covered with shallow water for some part of the year. Bogs, swamps, marshes, and sloughs are types of wetlands.

Wetlands help improve water quality, store floodwaters, reduce erosion, and recharge groundwater. They are also habitat for wildlife and home to about one-third of our endangered species, though our focus is on wetlands for waste treatment. The treatment process involves complex physical, biological, and chemical interactions, but it can be simply described.

If surface runoff flows through wetlands before reaching open water, its progress will be slower here than in channelized flows over drier lands. Suspended solids will settle or filter out, and microorganisms will pick up the organics and nutrients in the water for food. Metals will settle into the soil and be absorbed by plants. Thus, pollutants in stormwater runoff can be reduced, cleansed, or transformed into harmless substances during the runoff's passage or treatment in natural or constructed wetlands. Most pollutants are transformed into basic elements, compost, or biomass.

The constructed wetland is the heart of the treatment system. It cleans wastewater by filtering and settling solids, decomposing organics, and adsorbing/absorbing other pollutants such as phosphorus and trace metals. The dissolved organic pollutants are removed by a complex group of microbes (bacteria, fungi, algae, and protozoa) that live in the wastewater and on plant and sediment surfaces. Since waste materials are food for most of these microbes, pollutants are gradually converted through complex food cycles into environmentally harmless by-products (gases that escape to the air and inert solids that stay in the system).

The primary purpose of wetland plants is to provide a place for these microbes to attach and grow. Generally, treatment effectiveness increases with plant density, which allows a larger quantity of attached microbes to exist within the system. The density of plants also affects flow hydraulics. Uniform flow is enhanced by uniform plant densities, but variable densities create short-circuiting which